Claims

[c1] BUR920030128US1
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1. A circuit, comprising:
a capacitor coupled between a first circuit node and a second circuit node and that leaks a leakage current from said first circuit node to said second circuit node; and
a compensation circuit adapted to supply a compensatory current to compensate for said leakage current to said first circuit node.

[c2] 2. The circuit of claim 1, wherein said second circuit node is ground.

[c3] 3. The circuit of claim 1, wherein said compensation circuit comprises:
an additional capacitor connected between a voltage source and said first circuit node.

[c4] 4. The circuit of claim 3, wherein the capacitance of said additional capacitor is about equal to the capacitance of said capacitor and the leakage of said additional capacitor is about equal to the leakage of said capacitor.

[c5] 5. The circuit of claim 1, wherein said compensation circuit comprises:
an additional capacitor and a voltage doubler, a first plate of said additional capacitor connected to said first circuit node, a second plate of said additional capacitor connected to an output of said voltage doubler, and an input to said voltage doubler connected to said first circuit node.

[c6] 6. The circuit of claim 1, wherein said compensation circuit comprises;
a current source connected between a voltage source and said first circuit node;
an additional capacitor connected between said second circuit node and a voltage buffer, said voltage buffer adapted to generate a voltage across said additional capacitor; based on the voltage on said first circuit node; and
a current monitor connected to said voltage buffer and adapted to control an amount of current supplied from said current source to said first circuit node based on a leakage current from said additional capacitor to said second circuit node.

[c7] 7. The circuit of claim 1, wherein said current source supplies an amount of current to said first circuit node

that is equal a leakage current of said additional capacitor times the capacitance of said capacitor divided by the capacitance of said additional capacitor.

[c8] 8. The circuit of claim 1, wherein said compensation circuit comprises:
a current source connected between a voltage source and said first circuit node;
a sensing element connected between said capacitor and said second circuit node; and
an operational amplifier, a first input of said amplifier connected to a third circuit node between said capacitor and said sensing element, a second input of said amplifier connected to said second circuit node, and the output of said amplifier adapted to control an amount of current supplied from said current source to said first circuit node based on an amount of said leakage current.

[c9] 9. The circuit of claim 8, wherein said sensing element is a resistor.

[c10] 10. The circuit of claim 1, wherein said compensation circuit comprises:
a current source connected between a voltage source and said first circuit node;
a voltage buffer connected to said first circuit node and adapted to sense a voltage on said first circuit node;

a time delay circuit connected between said voltage buffer and a first input of an operational amplifier, a second input of said operational amplifier connected between said voltage buffer and said time delay circuit, said operational amplifier generating an output signal; and

said output signal of said operational amplifier coupled to said current source in order to control an amount of current supplied from said current source to said first circuit node based on said output signal of said operational amplifier.

[c11] 11. The circuit of claim 1, wherein said compensation circuit comprises;

a reference resistor coupled between said first and second circuit nodes;

a current reference circuit coupled to the gate of a pass gate, the source/drains of said pass gate coupled between a voltage source and said first circuit node;

a digital to analog converter connected to said current reference and adapted to control a voltage applied by said current reference to said gate of said pass gate; and

a leakage reference circuit adapted to sense a voltage on said second node, said current reference including a reference capacitor, said leakage reference circuit generating a reference current proportional to the ratio of the

capacitance of said reference capacitor to the capacitance of said capacitor and adapted to supply an amount of compensating current to said first circuit node that is about equal to said leakage current.

[c12] 12. The circuit of claim 1, wherein said compensation circuit comprises;
a reference resistor coupled between said first and second circuit nodes;
a current reference circuit coupled to the gate of a pass gate, the source/drains of said pass gate coupled between a voltage source and said first circuit node;
a digital to analog converter connected to said current reference and adapted to control a voltage applied by said current reference to said gate of said pass gate; and
a leakage reference circuit adapted to sense a voltage on said second node, said current reference including a reference capacitor, said leakage reference circuit generating a reference current proportional to the ratio of the capacitance of said reference capacitor to the capacitance of said capacitor and adapted to drain an amount of current from said current reference circuit such that said pass gate supplies an amount of compensating current to said first circuit node that is about equal to said leakage current.

[c13] 13. The circuit of claim 1, wherein said capacitor is selected from the group consisting of a PFET capacitor, an NFET capacitor, a metal-insulator-metal capacitor, a trench capacitor, a deep trench capacitor, an electrolytic capacitor, a tantalum capacitor, a mica capacitor and a ceramic capacitor.

[c14] 14. The circuit of claim 1, further including:
means for supplying a correction current to said first node at a correction frequency;
means for switching said compensatory current off when said correction frequency is greater than a multiple of an equivalent frequency of said compensatory current and for switching said compensatory current on when said correction frequency is less than said multiple of said equivalent compensatory current frequency; and
wherein said equivalent compensatory current frequency is defined as one divided by the effective resistance of said capacitor attributable to said leakage current, times the capacitance of said capacitor.

[c15] 15. A phase locked loop circuit, comprising:
an output of a phase detector connected to the input of a charge pump;
an input of a compensated loop filter connected to an output of said charge pump;
an input of a voltage controlled oscillator connected to

the output of said compensated loop filter;
and output of said voltage controlled oscillator connected to an input of said phase detector; and
said compensated loop filter comprising:
a capacitor coupled between a first circuit node and a second circuit node that leaks a leakage current from said first circuit node to said second circuit node;
a secondary resistor connected between said first circuit node and a secondary capacitor, said secondary capacitor connected between said secondary resistor and said second circuit node; and
a compensation circuit adapted to supply a compensatory current to compensate for said leakage current to said first circuit node.

[c16] 16. The circuit of claim 15, wherein said second circuit node is ground.

[c17] 17. The circuit of claim 15, wherein said compensation circuit comprises:
an additional capacitor connected between a voltage source and said first circuit node.

[c18] 18. The circuit of claim 15, wherein the capacitance of said additional capacitor is about equal to the capacitance of said capacitor and the leakage of said additional capacitor is about equal to the leakage of said capacitor.

[c19] 19. The circuit of claim 15, wherein said compensation circuit comprises:
an additional capacitor and a voltage doubler, a first plate of said additional capacitor connected to said first circuit node, a second plate of said additional capacitor connected to an output of said voltage doubler, and an input of said voltage doubler connected to said first circuit node.

[c20] 20. The circuit of claim 15, wherein said compensation circuit comprises;
a current source connected between a voltage source and said first circuit node;
an additional capacitor connected between said second circuit node and a voltage buffer, said voltage buffer adapted to generate a voltage across said additional capacitor; based on the voltage on said first circuit node; and
a current monitor connected to said voltage buffer and adapted to control an amount of current supplied from said current source to said first circuit node based on a leakage current from said additional capacitor to said second circuit node.

[c21] 21. The circuit of claim 15, wherein said current source supplies an amount of current to said first circuit node

that is equal a leakage current of said additional capacitor times the capacitance of said capacitor divided by the capacitance of said additional capacitor.

[c22] 22. The circuit of claim 15, wherein said compensation circuit comprises:
a current source connected between a voltage source and said first circuit node;
a sensing element connected between said capacitor and said second circuit node; and
an operational amplifier, a first input of said amplifier connected to a third circuit node between said capacitor and said sensing element, a second input of said amplifier connected to said second circuit node, and the output of said amplifier adapted to control an amount of current supplied from said current source to said first circuit node based on an amount of said leakage current.

[c23] 23. The circuit of claim 22, wherein said sensing element is a resistor.

[c24] 24. The circuit of claim 15, wherein said compensation circuit comprises:
a current source connected between a voltage source and said first circuit node;
a voltage buffer connected to said first circuit node and adapted to sense a voltage on said first circuit node;

a time delay circuit connected between said voltage buffer and a first input of an operational amplifier, a second input of said operational amplifier connected between said voltage buffer and said time delay circuit, said operational amplifier generating an output signal; and

said output signal of said operational amplifier coupled to said current source in order to control an amount of current supplied from said current source to said first circuit node based on said output signal of said operational amplifier.

[c25] 25. The circuit of claim 15, wherein said compensation circuit comprises;

a reference resistor coupled between said first and second circuit nodes;

a current reference circuit coupled to the gate of a pass gate, the source/drains of said pass gate coupled between a voltage source and said first circuit node;

a digital to analog converter connected to said current reference and adapted to control a voltage applied by said current reference to said gate of said pass gate; and

a leakage reference circuit adapted to sense a voltage on said second node, said current reference including a reference capacitor, said leakage reference circuit generating a reference current proportional to the ratio of the

capacitance of said reference capacitor to the capacitance of said capacitor and adapted to supply an amount of compensating current to said first circuit node that is about equal to said leakage current.

[c26] 26. The circuit of claim 15, wherein said compensation circuit comprises;
a reference resistor coupled between said first and second circuit nodes;
a current reference circuit coupled to the gate of a pass gate, the source/drains of said pass gate coupled between a voltage source and said first circuit node;
a digital to analog converter connected to said current reference and adapted to control a voltage applied by said current reference to said gate of said pass gate; and
a leakage reference circuit adapted to sense a voltage on said second node, said current reference including a reference capacitor, said leakage reference circuit generating a reference current proportional to the ratio of the capacitance of said reference capacitor to the capacitance of said capacitor and adapted to drain an amount of current from said current reference circuit such that said pass gate supplies an amount of compensating current to said first circuit node that is about equal to said leakage current.

[c27] 27. The circuit of claim 15, wherein said capacitor is selected from the group consisting of a PFET capacitor, an NFET capacitor, a metal-insulator-metal capacitor, a trench capacitor, a deep trench capacitor, an electrolytic capacitor, a tantalum capacitor, a mica capacitor and a ceramic capacitor.

[c28] 28. The circuit of claim 15, further including:
means for supplying a correction current to said first node at a correction frequency;
means for switching said compensatory current off when said correction frequency is greater than a multiple of an equivalent frequency of said compensatory current and for switching said compensatory current on when said correction frequency is less than said multiple of said equivalent compensatory current frequency; and
wherein said equivalent compensatory current frequency is defined as one divided by the effective resistance of said capacitor attributable to said leakage current, times the capacitance of said capacitor.

[c29] 29. A method of compensating a capacitor that leaks current between a first circuit node and a second circuit node, comprising:
providing said capacitor;
coupling said capacitor between said first circuit node and said second circuit node; and

coupling to said first circuit node, a compensation circuit adapted to supply a compensatory current to compensate for said leakage current to said first circuit node.

[c30] 30. The method of claim 29, wherein said second circuit node is ground.

[c31] 31. The method of claim 29, wherein said compensation circuit comprises:
an additional capacitor connected between a voltage source and said first circuit node.

[c32] 32. The method of claim 31, wherein the capacitance of said additional capacitor is about equal to the capacitance of said capacitor and the leakage of said additional capacitor is about equal to the leakage of said capacitor.

[c33] 33. The method of claim 29, wherein said compensation circuit comprises:
an additional capacitor and a voltage doubler, a first plate of said additional capacitor connected to said first circuit node, a second plate of said additional capacitor connected to an output of said voltage doubler, and an input to said voltage doubler connected to said first circuit node.

[c34] 34. The method of claim 29, wherein said compensation circuit comprises;

a current source connected between a voltage source and said first circuit node;
an additional capacitor connected between said second circuit node and a voltage buffer, said voltage buffer adapted to generate a voltage across said additional capacitor; based on the voltage on said first circuit node; and
a current monitor connected to said voltage buffer and adapted to control an amount of current supplied from said current source to said first circuit node based on a leakage current from said additional capacitor to said second circuit node.

[c35] 35. The method of claim 29, wherein said current source supplies an amount of current to said first circuit node that is equal a leakage current of said additional capacitor times the capacitance of said capacitor divided by the capacitance of said additional capacitor.

[c36] 36. The method of claim 29, wherein said compensation circuit comprises:
a current source connected between a voltage source and said first circuit node;
a sensing element connected between said capacitor and said second circuit node; and
an operational amplifier, a first input of said amplifier connected to a third circuit node between said capacitor

and said sensing element, a second input of said amplifier connected to said second circuit node, and the output of said amplifier adapted to control an amount of current supplied from said current source to said first circuit node based on an amount of said leakage current.

[c37] 37. The method of claim 36, wherein said sensing element is a resistor.

[c38] 38. The method of claim 29, wherein said compensation circuit comprises:

a current source connected between a voltage source and said first circuit node;

a voltage buffer connected to said first circuit node and adapted to sense a voltage on said first circuit node;

a time delay circuit connected between said voltage buffer and a first input of an operational amplifier, a second input of said operational amplifier connected between said voltage buffer and said time delay circuit, said operational amplifier generating an output signal; and

said output signal of said operational amplifier coupled to said current source in order to control an amount of current supplied from said current source to said first circuit node based on said output signal of said operational amplifier.

[c39] 39. The method of claim 29, wherein said compensation circuit comprises;
a reference resistor coupled between said first and second circuit nodes;
a current reference circuit coupled to the gate of a pass gate, the source/drains of said pass gate coupled between a voltage source and said first circuit node;
a digital to analog converter connected to said current reference and adapted to control a voltage applied by said current reference to said gate of said pass gate; and
a leakage reference circuit adapted to sense a voltage on said second node, said current reference including a reference capacitor, said leakage reference circuit generating a reference current proportional to the ratio of the capacitance of said reference capacitor to the capacitance of said capacitor and adapted to supply an amount of compensating current to said first circuit node that is about equal to said leakage current.

[c40] 40. The method of claim 29, wherein said compensation circuit comprises;
a reference resistor coupled between said first and second circuit nodes;
a current reference circuit coupled to the gate of a pass gate, the source/drains of said pass gate coupled between a voltage source and said first circuit node;

a digital to analog converter connected to said current reference and adapted to control a voltage applied by said current reference to said gate of said pass gate; and a leakage reference circuit adapted to sense a voltage on said second node, said current reference including a reference capacitor, said leakage reference circuit generating a reference current proportional to the ratio of the capacitance of said reference capacitor to the capacitance of said capacitor and adapted drain an amount of current from said current reference circuit such that said pass gate supplies an amount of compensating current to said first circuit node that is about equal to said leakage current.

[c41] 41. The method of claim 29, wherein said capacitor is selected from the group consisting of a PFET capacitor, an NFET capacitor, a metal-insulator-metal capacitor, a trench capacitor, a deep trench capacitor, an electrolytic capacitor, a tantalum capacitor, a mica capacitor and a ceramic capacitor.

[c42] 42. The method of claim 29, further including:
supplying a correction current to said first node at a correction frequency;
switching said compensatory current off when said correction frequency is greater than a multiple of an equivalent frequency of said compensatory current and switch-

ing said compensatory current on when said correction frequency is less than said multiple of said equivalent compensatory current frequency; and

wherein said equivalent compensatory current frequency is defined as one divided by the effective resistance of said capacitor attributable to said leakage current, times the capacitance of said capacitor.